DRY MAGNETIC SEPARATION OF INSOL FROM SYLVITE AND HALITE

FINAL REPORT

CENTRAL CANADA POTASH DIVISION
NORANDA MINERALS INC.

COLONSAY, SASKATCHEWAN

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SUMMARY

1. Generally lower water insoluble levels can be attained magnetically on OCP ores than by the scrubbing-desliming process in current mill use with none of the attendant sylvite particle degradation. Additional testing is recommended to establish the impact on subsequent unit operations in conventional potash mills.

2. Several magnetic circuits deemed of practical importance have been evolved. These require pilot plant confirmatory investigation.

3. Other Patience Lake member ores are amenable to the magnetic separating process.

4. Preliminary investigation into altering the magnetic susceptibilities of halite or sylvite selectively was partially successful. Investigation of this concept should continue.

SOMMAIRE

1. La séparation magnétique fait l'argile plus bas qu'est possible avec la méthode normale (scrub-deslime). Les particules des chlorule de potassium n'sont pas dégénérés cependant. Il est nécessaire à continuer cette recherche pour s'établir l'effet dans les opérations suivants de la usine.

2. Plusiers circuites magnétiques d'importance practiques ont été dévelopes. Il est nécessaire à confirmer ça dans l'usine pilote.

3. Les autres minerais du Lac Patience réponds bien à la séparation magnétique.

4. L'investigation préliminaire dans le modification du susceptibilitiés magnétiques de chlorule de natruim ou chlorule de potassium selectivement fus réussi partialement. Il est nécessaire à continuer cette recherche.

ADDENDUM

This report represents in excess of three months effort by various personnel during which time some 220 magnetic separations and 60 gravity (heavy liquid) separations were completed resulting in more than 1,000 KCl and 1,000 water insoluble analyses. Iron determinations on various products were also involved.

Not all obtained results have been published — nor was this intended. Voluminous tabulations often obscure rather than enlighten so these were minimized and simplified to the greatest possible extent. The published results do however highlight the effectiveness of this novel technology in clay removal from potash ores. There is no reason to doubt the ability to duplicate results with this equipment given reasonably consistent component liberation.

Notes and results pertinent to this project are on file at Central Canada Potash Analytical Laboratory. These are available for perusal or copying by project participants.

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Mr. Bo R. Arvidson, Vice-President-Marketing of Oresorters (North America) Inc. deserves special thanks for his enthusiastic advice, discussions and direction as well as the many imposed inconveniences in respect to the rental and application of the Permroll in this novel process.

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INTRODUCTION

During 1985, laboratory work on clay removal from potash ores was completed using a Frantz Isodynamic magnetic separator. Results were encouraging despite limitations in terms of particle size and throughput. Concurrently a Bateman Permroll temporarily located at Lakefield Research, Peterborough, Ontario demonstrated its practicality for this application. The Permroll is a high intensity, high gradient (1.5 to 2 Tesla) permanent magnet roll designed to test the susceptibility of a large variety of mineral ores to separation.

Under the auspices of the Saskatchewan Potash Producers Association as a joint research project of Central Canada Potash, the Potash Corporation of Saskatchewan, Cominco and the Potash Company of America, and with CANMET co-funding, the primary objective was to establish a viable circuit (or circuits) for future pilot plant confirmation. Secondary objectives included compatibility tests on ore from project participants, clay liberation studies and preliminary attempts to selectively improve the magnetic susceptibility of halite.

It is estimated some 60% of the water insoluble content of Central Canada Potash ore occurs as massive bands, hence establishing a magnetic separating circuit underground would ensure the greatest benefit to the operation and since mill crushing practice is concerned with optimizing sylvite liberation, a clay liberation study was deemed important.

Despite similar physical-chemical properties coupled with constraints of time, facilities and expertise, exploratory tests to selectively alter the magnetic susceptibility of the sylvite-halite ore components were included. Any degree of success would reinforce the importance of magnetic separation, particularly, if halite were induced to associate with the water insoluble material. This was recognized to be a complex, novel endeavour and little if any success was anticipated.

Given a practical circuit underground, economic benefits would be maximized. These include:

(a) Environmental

Removal of an appreciable quantity of liberated clay undergound would minimize dust content and dusting potential of the residual ore, besides providing dry backfill material. Considering the possible need to remove -200 mesh fines to ensure adequate magnetic separator performance, some 12% of the initial ore could possibly be rejected. This would not represent a recovery loss since practical mill desliming is in this range but would impact positively on the surface tailings disposal area.

(b) Hoisting Capacity

At the present hourly hoisting rate and a 40% KCl, 5% WI content of the ore as mined, an estimated 21 tons of water insoluble, 26 tons of KCl and 37 tons of NaCl would remain underground. Hoisting capacity in terms of KCl would increase.

(c) Scrubbing-Desliming

Requirements for both process functions would decrease significantly, if not entirely. This should equate to worthwhile savings in terms of maintenance, power, reagents and operating labour. Additionally, particle degeneration associated with high intensity scrubbing would be minimized resulting in lower drying, compacting and crystallization costs as well as improve recovery.

(d) Brine Recovery System

The possible significant reduction of clay content in the cold slime thickener feed should simplify circuit performance, decrease power consumption and maintenance costs.

TEST RESULTS AND DETAILS

CIRCUIT OPTIMIZATION (TASK 1)

I TYPICAL ORE FRACTIONAL ANALYSES

As mined, Central Canada Potash ore is generally composed of halite, sylvite (potash) and clay (water insoluble) in the approximate ratios of 55:40:5. Sylvite is recovered for agricultural purposes while the halite and clay components are rejected and stockpiled on surface as a tailing. A ton of concentrate is produced from approximately 2.7 tons of ore. Potash recovery is initiated by dry crushing to -6 mesh.

The resultant size spectrum ensures adequate potash liberation for high recovery. Flotation is the main recovery vehicle and since clay is detrimental to this process in terms of recovery, grade and efficient reagent utilization, the clay (in current practice) is degenerated by high intensity scrubbing and removed by mechanical desliming to somewhat below 2.5% WI content in the flotation feed. This operation also degenerates the KCl very significantly. Thus only about 80% of the original cumulative +20 mesh KCl content is available for rougher flotation. A process that would reduce or, preferably, eliminate this degeneration is highly desirable. Removal of liberated clay magnetically is such a process.

A typical fractional analyses follows. The KCl and WI assay values are actual. The NaCl values are obtained by difference. The WI (clay) results suggest this to be the toughest ore component with perhaps a tendency to concentrate, or liberate indifferently, in the +8 mesh range. Additionally, a concentration of clay values occurs in the -65 mesh portion. This is deemed to be due to degeneration of the massive clay portions coupled with liberation of more finely disseminated clay values which normally do not liberate in the coarser clay fractions. The NaCl distribution suggests it to be somewhat more refractive to impact breakage than KCl.

Size fractional KCl values are higher than the head value in the 20 to 65 mesh range, falling off at either end. The reverse generally holds true for the WI (clay) and the NaCl values.

TABLE I

TYPICAL ORE FRACTIONAL ANALYSES

Mesh	% Weight Retained	Analyses %			Distribution %		
		KCl	NaCl	WI	KCl	NaCl	WI
6	2.3	23.5	67.4	9.1	1.4	2.8	4.1
8	12.6	29.3	62.5	8.2	9.3	14.3	20.1
10	13.9	35.9	58.3	5.8	12.6	14.7	15.7
14	13.9	39.7	56.0	4.3	13.9	14.1	11.6
20	11.0	43.6	53.1	3.3	12.1	10.6	7.1
28	10.4	43.2	53.5	3.3	11.3	10.1	6.7
35	8.4	45.6	51.4	3.0	9.7	7.8	4.9
48	8.7	46.3	50.5	3.2	10.2	7.9	5.4
65	4.6	47.0	48.0	5.0	5.5	4.0	4.4
100	5.7	44.1	50.5	5.6	6.3	5.2	6.2
150	1.9	41.4	52.6	6.0	2.0	1.8	1.9
200	2.3	38.0	54.8	7.2	2.2	2.3	3.2
-200	4.3	32.6	57.1	10.3	3.5	4.4	8.7
Total	100.0	39.6	55.3	5.1	100.0	100.0	100.0

NOTE: NaCl analyses by difference

II MAGNETIC REMOVAL OF CLAY

A beltless Bateman Permroll was used in these tests. It was chosen in preference to a belt type unit since the low magnetic susceptibility of the ore components presented no difficulty in removal from the magnetic roll surface. Additionally, a belt reduces the magnetic gradient hence affecting the separation performance adversely.

The test program examined Permroll performance on individual ore size fractions as well as on various combinations. These included 6, 8, 10, 14, 20, 28, 35, 48, 65 and 100 mesh fractions; 6 x 28, 28 x 48, 48 x 100, -100 mesh combinations; 6 x 8, 8 x 14, 14 x 28, 48 x 100, -100 mesh combinations as well as 6 x 100 mesh and 6 x 200 mesh ore.

A. TESTS ON INDIVIDUAL SIZE FRACTIONS

This test series confirms the effectiveness of magnetic technology for clay rejection. As illustrated in Table I, fractional KCl values are lower than average head values in the 6 x 10 mesh range, exceed this value in the 14 x 100 mesh range, and then fall below head values in the remaining size spectrum. The inverse essentially holds for the WI (clay) and NaCl contents.

The series was conducted under very similar conditions in terms of roll speed (100 RPM), feeder vibration (70%) and feed rate. Slight changes to the splitter blade were made as deemed necessary to accommodate slight deflection differences size by size, thus ensuring adequate results. Heavy liquid separation of the non-magnetic portions corroborated the effectiveness of magnetic separation into the 35 mesh range. Beyond this, separation effectiveness deteriorates due to magnetic flocculation and electrostatic effect. This problem could probably be overcome by using weaker magnet rolls. Test results are presented in Table II.

Although ensuring the best possible conditions for magnetic separating, it is doubtful such a circuit could be tolerated in practice even if the task of screening the ore into ten or eleven portions were not too formidable. More practical circuits entail treatment of wider size ranges in a single stage or multi-stage arrangement.

TABLE II

EFFECT OF PARTICLE SIZE ON CLAY REJECTION MAGNETICALLY

	Magnetics					Non Magnetics							
		Analyses %		Dist'n %			Analyses %			Dist'n %		Head	
Mesh	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	WI(HL)*	KCl	WI	KCl	WI
+ 6	6.0	22.6	42.5	4.8	54.1	94.0	28.8	2.3	1.9	95.2	45.9	28.4	4.7
+ 8	7.7	22.8	37.4	5.4	62.1	92.3	33.6	1.9	1.8	94.6	37.9	32.8	4.6
+ 10	8.7	25.6	30.6	6.0	66.0	91.3	38.3	1.5	1.6	94.0	34.0	37.2	4.0
+ 14	8.6	28.3	27.3	6.1	70.0	91.4	40.9	1.1	1.2	93.9	30.0	39.8	3.4
+ 20	7.5	30.6	27.6	5.4	67.0	92.5	43.8	1.1	1.1	94.6	33.0	42.8	3.1
+ 28	6.6	34.4	24.5	5.0	61.2	93.4	46.2	1.1	1.0	95.0	38.8	45.4	2.6
+ 35	5.1	35.9	36.8	4.0	62.2	94.9	45.8	1.2	1.2	96.0	37.8	45.3	2.0
+ 48	5.0	40.5	34.0	4.4	54.4	95.0	46.0	1.5	—	95.6	45.6	45.7	3.1
+ 65	4.6	40.0	35.0	4.0	47.0	95.4	46.1	1.9	—	96.0	53.0	45.8	3.4
+100	2.8	36.5	40.0	2.3	33.4	97.2	44.7	2.3	—	97.7	66.6	44.5	3.4
Avg.	6.8	29.9	31.5	5.0	60.8	93.7	41.6	1.5		95.0	39.2	40.8	3.5

* Heavy liquid separations at a specific gravity of 2.2 suggest the ultimate level of WI rejection

B. POSSIBLE MAGNETIC CIRCUITS

A successful magnetic separating circuit should be capable of yielding a high grade (predominately clay) discard product with a minimum KCl loss. Analyses of clay with a specific gravity higher than 2.46 suggests the following elementary average composition: water soluble KCl 10.6%, water soluble NaCl 14.8%, water insoluble (clay) 74.6%. The KCl-NaCl portion is deemed to originate from brine absorbed by the clay. Thus KCl values significantly exceeding 11% represent a recoverable loss. Since it is likely this potash tends to be somewhat magnetic, it would ultimately be recovered with a lower intensity magnet. (A belted Permroll might be applicable. This would allow higher roll speeds, increasing throughput rates.)

Several circuit configurations, deemed to be of practical interest, were investigated. These were:

1) Single Stage/Single Pass

This circuit can ensure a rejectable magnetic product and a non-magnetic product with a WI content lower than 2%. Although very effective, throughput is limited.

2) Series Multiple Stage

Two combinations are possible. One entails the production of a rejectable magnetic (clay) portion in each stage; the second an acceptable non-magnetic portion in each stage. To our mind, the first was the preferred system since visual interpretation of results was readily possible. Throughput rates can be doubled or even tripled compared to a single stage/single pass system. Generally, three stages yield adequate results.

3) Single Stage/Reprocessing of Magnetics

This circuit increases throughput rates significantly over the two previous cases and also entails smaller equipment in the reprocessing stage or stages. There appears to be sufficient migration of magnetics towards the roll surface to result in about 50% of the feed reporting as an acceptable non-magnetic product. The balance reporting as magnetics (or so called middling) is reprocessed into rejectable magnetic and non-magnetic fractions.

4) Series Stage/Reprocessing of Magnetics

This yields better control of the middling type magnetics for reprocessing. Generally a dual roughing stage coupled with resultant magnetics reprocessing yields acceptable results.

5) Series Stage/Screening of Magnetic Middlings Prior to Reprocessing

This adaptation seems to be particularly suitable for total ore treatment. It involves screening of magnetic middlings at 8 and 28 mesh and reprocessing the resultant 28 mesh products. In practice, the +8-mesh magnetic fraction could be reprocessed to scavenge KCl from this lightweight product. This was omitted in the testing because of the small quantities involved.

TABLE III

TYPICAL RESULTS OF SINGLE STAGE/SINGLE PASS TESTS

Mesh	Magnetics					Non Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
6 x 28	10.5	31.1	30.0	8.8	72.5	89.5	37.6	1.3	91.2	27.5	37.0	4.3
28 x 48	5.0	33.0	32.1	4.0	58.5	95.0	41.5	1.2	96.0	41.5	41.1	2.7
48 x 100	28.8	42.0	4.8	28.8	40.9	71.2	42.0	2.8	71.2	59.1	42.0	3.4
Average	11.5	34.3	23.1	9.9	66.4	88.5	40.3	1.5	90.1	33.5	39.6	4.0
6 x 8	12.7	23.2	43.5	10.6	76.0	87.3	28.5	2.0	89.4	24.0	27.8	7.3
8 x 14	9.5	26.3	34.0	7.5	78.1	90.5	34.2	1.0	92.5	21.9	33.4	4.1
14 x 28	7.0	31.7	30.8	5.6	72.0	93.0	39.9	0.9	94.4	28.0	39.3	3.0
28 x 48	6.4	36.9	27.0	5.7	52.1	93.6	41.5	1.7	94.3	47.9	41.2	3.3
48 x 100	28.8	42.0	4.8	28.8	40.9	71.2	42.0	2.8	71.2	59.1	42.0	3.4
Average	11.0	32.2	29.4	9.8	71.7	89.0	36.8	1.4	90.2	28.3	36.3	4.5
6 x 100	9.4	35.4	23.2	9.2	58.6	90.6	36.3	1.7	90.8	41.4	36.2	3.9
	10.2	33.9	28.9	10.0	65.9	89.8	34.8	1.7	90.0	34.1	34.7	4.5
	8.7	31.8	32.0	8.1	61.6	91.3	34.4	1.9	91.9	38.4	34.2	4.5
6 x 200	11.4	33.1	26.4	10.7	64.1	88.6	35.5	1.9	89.3	35.9	35.2	4.7
	12.1	33.8	21.4	12.2	57.6	87.9	33.2	1.9	86.4	37.7	33.7	4.5
	10.0	32.0	31.0	9.4	60.5	90.0	34.0	2.2	89.5	33.5	33.8	5.1

6) Three Product Circuit

Although it might be possible to produce a high-grade clay product, a so called middling product (from which KCl could be salvaged) and an acceptable non-magnetic product with the Permroll, time constraints did not permit investigation of this possibility.

C PERFORMANCE OF VARIOUS CIRCUITS

1) Single Stage/Single Pass

To ensure best results feed must be presented in a uniform, thin layer. This constraint hampers feed rates somewhat, but selectivity is excellent. Tables II and III show typical results.

Table II lists results on individual size fractions, whereas Table III highlights those obtained on several size ranges. Considering a 6 x 100 mesh size range, treatment of individual size fractions yields the best overall results. Clay rejection efficiency improves with diminishing size, but decreases in the 48 mesh range due very likely to magnetic flocculation or clumping of the fines in the strong magnetic field. A weaker magnet would probably overcome this condition. Heavy liquid separations on non-magnetic fractions at a specific gravity of 2.2 confirm the effectiveness of magnetic separation. Additionally, the heavy liquid sinks (rejects) showed a predominance of middlings and disseminated clay rather than definite clay particles, suggesting that particles with the highest magnetic susceptibility had been removed.

A tabulation of heavy liquid separations (specific gravity 2.2) on non-magnetic portions of various size ranges follows.

TABLE IV

HEAVY LIQUID SEPARATION OF NON-MAGNETICS
(confirming effectiveness of magnetic separation)

Mesh	Non-Magnetic				Comments
	Original		Heavy Liquid Spg. 2.2		
	% KCl	% WI	% KCl	% WI	
6 x 8	31.0	2.7	33.1	1.2	Mostly middlings in sink
8 x 14	37.0	2.0	40.7	1.1	About 30% fine clay in sink
14 x 28	40.0	1.2	43.6	0.9	Vitreous crystal dominant in sink
28 x 48	42.7	1.3	44.4	0.8	Vitreous crystal dominant in sink

When dealing with wider size ranges results parallel those on individual size fractions. Again clay rejection decreases with decreasing particle size (see results on 48 x 100 size fraction, Table III), but as already mentioned lower strength magnetic rolls would probably improve clay rejection without any great loss of throughput.

Tables II and III illustrate the consistency of magnetic separation regardless of size range treated. Thus the weighted average results for the various size components compare very favourably with those on 6 x 100 mesh ore. It is also noted that even with the high strength Permroll, the magnetic flocculating effect of the fines is significantly reduced when treating near total ore compared to treating sized fines fractions. This is likely due to the dilution effect of coarser particles which predominate in the case of the ore (ie the concentration of fines is significantly lower than in the case of sized fines). This effect is highlighted in Table V below.

TABLE V

EFFECT OF FINES ON MAGNETIC SEPARATION

	Magnetics					Non-Magnetics					Head %	
		Assays %		Dist'n %			Assays %		Dist'n %			
Mesh	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
6 x 200	11.4	33.1	26.4	10.7	64.1	88.6	35.5	1.9	89.3	35.9	35.2	4.7
6 x 100	8.7	31.8	32.0	8.1	61.6	91.3	34.4	1.9	91.9	38.4	34.2	4.5
48 x 100	28.8	42.0	4.8	28.8	40.9	71.2	42.0	2.8	71.2	59.1	42.0	3.4
- 100	21.1	29.9	8.7	21.1	22.3	79.9	31.4	8.0	79.9	77.7	31.4	8.2

Additionally, when treating near total ore the fines tend to follow the magnetic fractions. Attempts to process total ore (as plant crushed) were discontinued due to heavy dusting but it is deemed practical to "dedust" plant crushed ore prior to magnetic separation.

2) Series Multiple Stage

This circuit configuration is capable of increasing throughput by a factor of two or three over the single stage circuit. Results suggest three to five stages would yield very acceptable results (ie. WI content below 2% in the non-magnetics). Since the higher throughput rates entail heavier roll loads, selectivity decreases. Reprocessing of magnetics would improve this. It is interesting to note that overall (weighted average) results are very similar regardless of size ranges treated and, additionally, they do not differ appreciably from single stage results. Three stage separation results are presented in Table VI, Flowsheet 1 and Table VII. Magnetics have been combined to simplify the tabulation. Detailed results of a typical three stage separation on 8 x 14 mesh ore follow. All products finally underwent heavy liquid separation to establish:

a) separating effectiveness measured by WI content of magnetics. These separations were done at a specific gravity of 2.2.

b) separating effectiveness measured by recoverable sylvite (KCl) content of magnetics.

TABLE VI

TYPICAL RESULTS OF SERIES MULTIPLE STAGE TESTS
(3 Stages)

Mesh	Magnetics					Non Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
6 x 28	8.8	30.4	31.7	7.1	59.7	91.2	38.0	2.1	92.9	40.3	37.3	4.7
28 x 48	6.7	34.3	28.9	5.3	54.7	93.3	43.0	1.7	94.7	45.3	42.7	3.5
48 x 100	18.7	40.8	11.6	18.4	64.1	81.3	41.9	1.5	81.6	35.9	41.7	3.4
Average	9.6	33.2	26.9	8.2	59.3	90.4	39.4	2.0	91.8	40.7	38.8	4.4
6 x 8	17.3	26.4	28.3	16.0	69.4	82.7	29.0	2.6	84.0	30.5	28.6	7.0
8 x 14	11.7	31.9	21.6	9.7	64.2	88.3	38.9	1.6	90.3	35.8	38.1	2.9
14 x 28	10.3	39.6	12.7	10.1	42.1	89.7	40.8	2.0	89.9	57.9	40.8	3.1
28 x 48	6.7	34.3	28.9	5.3	54.7	93.3	43.0	1.7	94.7	45.3	42.7	3.5
48 x 100	18.7	40.8	11.6	18.4	64.1	81.3	41.9	1.5	81.6	35.9	41.7	3.4
Average	12.2	33.9	16.0	10.8	56.9	87.8	39.0	1.9	89.2	47.6	38.3	3.4
6 x 100	9.2	30.7	34.7	7.9	77.8	90.8	36.2	1.0	92.1	22.2	35.7	4.1
6 x 100	9.3	31.9	33.5	8.6	68.2	90.7	34.7	1.6	91.4	31.8	34.5	4.6
6 x 100	10.6	32.0	31.3	10.0	69.8	89.4	34.3	1.6	90.1	30.1	34.0	4.7
6 x 200	13.7	32.3	27.1	13.1	72.9	86.3	34.0	1.6	86.9	27.1	33.8	5.1

FLOWSHEET 1

SERIES MULTIPLE STAGE

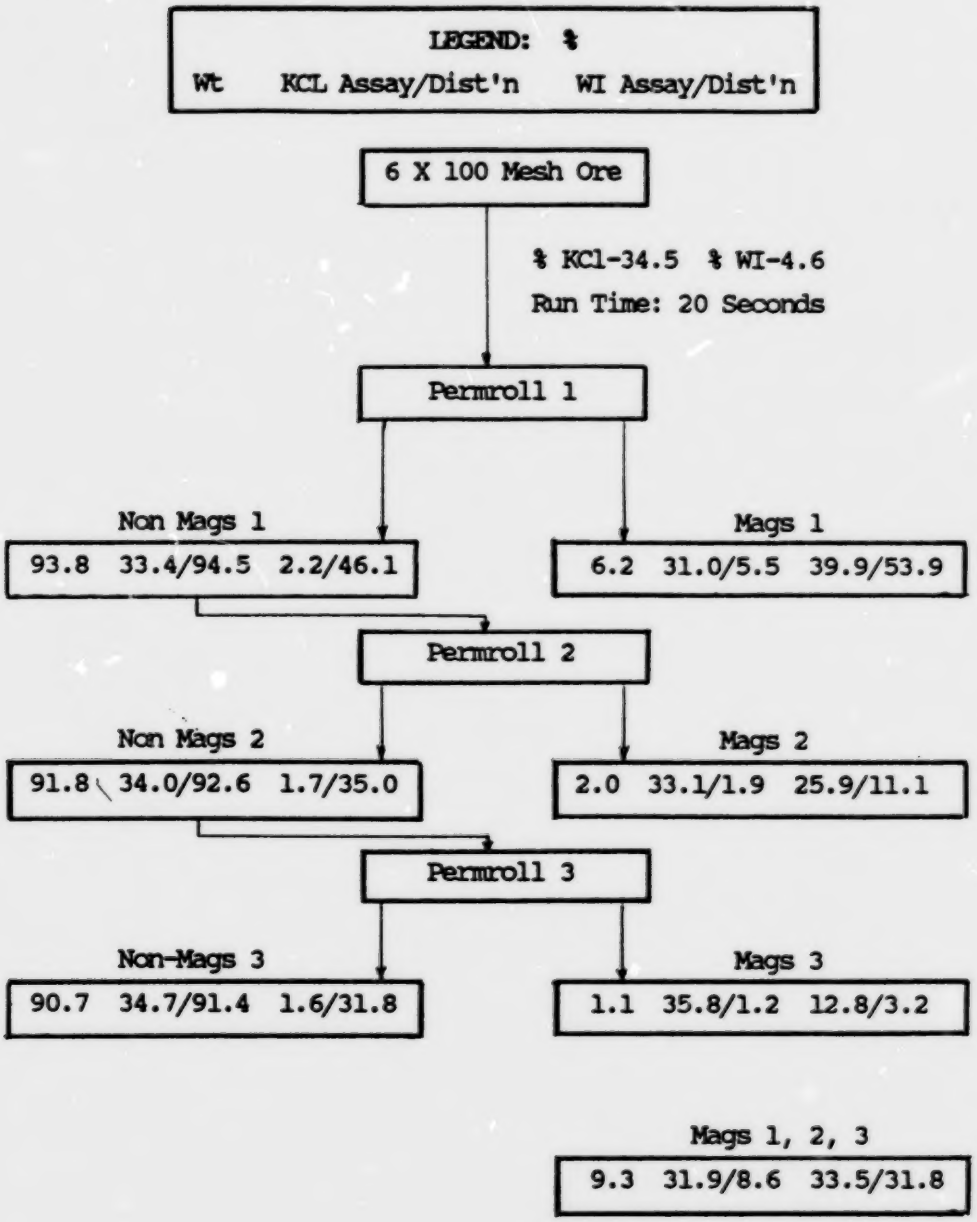


TABLE VII

THREE STAGE SEPARATION (8 x 14 Mesh Ore)
(showing stage by stage effect)

	% Wt	Assays % KCl	Assays % WI	Dist'n % KCl	Dist'n % WI
Non Mags	88.3	38.9	1.6	90.3	35.8
Mags 3	2.5	33.7	17.3	2.2	11.1
Non Mags 2*	90.8	38.9	2.0	92.5	46.9
Mags 2	3.5	32.0	21.1	2.9	18.7
Non Mags 1*	94.3	38.5	2.7	95.4	65.6
Mags 1	5.7	31.0	23.8	4.6	34.4
Head*	100.0	38.0	3.9	100.0	100.0
Mags 1 & 2*	9.2	31.4	22.8	7.5	53.1
Mags 1, 2 & 3*	11.7	31.9	21.6	9.7	64.2

* calculated values

Heavy liquid separation of the non-magnetic fraction at 2.2 specific gravity showed best possible WI level to be 1.0. The sink product represented some 40% of WI value and showed considerable middling material. The magnetic fractions were separated at 2.05 specific gravity, which level was deemed to represent recoverable KCl in the "float" portion. This yielded a product averaging 48.5% KCl and 4.9% WI representing 8.2% and 7.2% of the total contents respectively. These results confirm the effectiveness of clay removal magnetically.

3) Single Stage/Reprocessing of Magnetics

This circuit can yield very good results at high throughput rates and is very flexible. Generally one stage of roughing which accumulates one half to two thirds of the feed in the non-magnetic portion followed by reprocessing of the residual magnetic portion ensures high clay rejection with low KCl losses and yields an acceptable non-magnetic material. Typical results are shown in Table VIII(A) and Flowsheet 2.

TABLE VIII(A)

TYPICAL RESULTS OF MIDDLINGS REPROCESSING TESTS

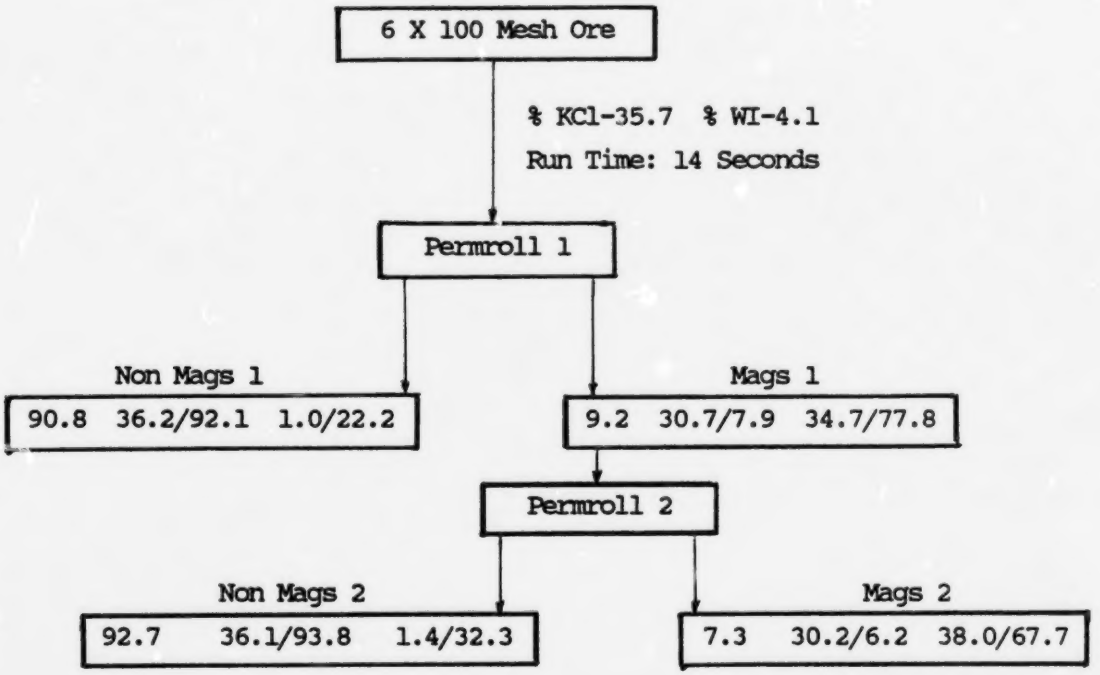
Single Stage Roughing/Single Stage Reprocessing

	Magnetics					Non Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
Mesh	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
6 x 8	6.7	23.9	47.1	10.9	55.9	93.3	26.7	2.7	89.1	44.1	27.9	5.6
8 x 14	7.9	25.1	24.7	5.5	58.2	92.1	37.2	1.5	94.5	41.8	36.3	3.4
8 x 14	7.4	25.1	45.4	5.4	61.7	92.6	35.2	2.2	94.6	38.4	34.4	5.3

FLOWSHEET 2

SINGLE STAGE ROUGHING WITH MAGNETICS REPROCESSED

LEGEND: %		
Wt	KCL Assay/Dist'n	WI Assay/Dist'n



4) Series Stage/Reprocessing of Magnetics

This circuit yields more consistent results than the single stage circuit since it ensures greater selectivity in the roughing stages and generally leaves a cleaner initial non-magnetic fraction. Results in terms of clay rejection and KCl retention are comparable to single stage/single pass results but feed rates for this circuit can be three to four times higher.

Results typical of this circuit are to be found in Table VIII(B) and Flowsheet 3.

TABLE VIII(B)

TYPICAL RESULTS OF MIDDLINGS REPROCESSING TESTS

Multi-Stage Roughing/Single Stage Reprocessing

	Magnetics					Non Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
Mesh	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
8 x 14	9.7	29.0	38.6	8.3	69.7	90.3	34.5	1.8	91.7	30.3	34.0	5.4
14 x 28	7.4	37.8	31.0	6.5	63.9	92.6	43.1	1.4	93.5	36.1	42.7	3.6
6 x 28	8.4	23.7	26.5	5.3	63.5	91.6	38.5	1.4	94.7	36.5	37.2	3.5
28 x 48	8.9	36.4	28.1	7.6	70.9	91.1	43.0	1.1	92.4	29.1	42.4	3.5

5) Series Stage/Screening Magnetic Middlings Prior to Reprocessing

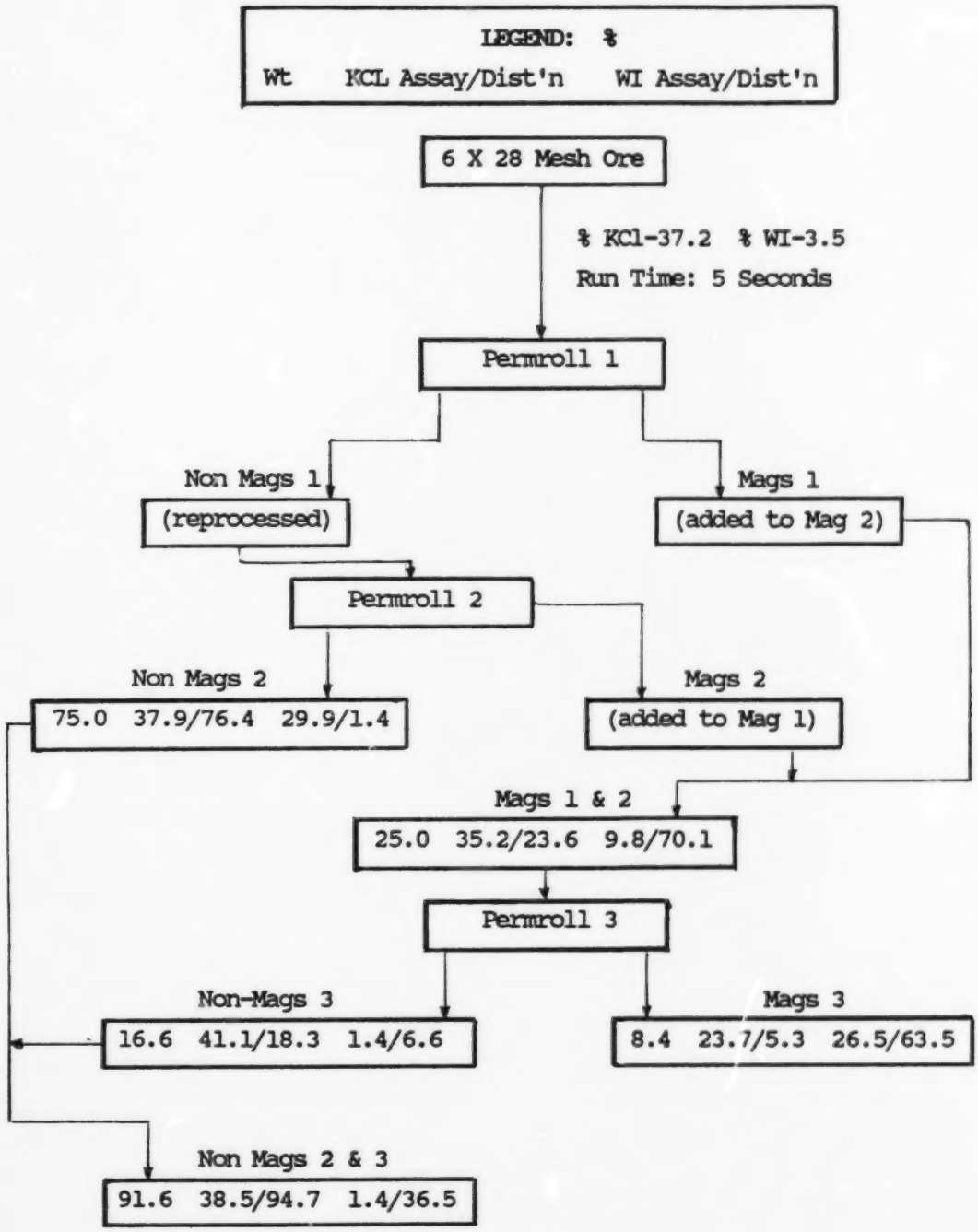
This circuit was established to effectively treat near total ore (either 6 x 100 or 6 x 200 mesh) at high throughput rates. Following two stages of roughing, the combined rougher magnetics were screened at 8 mesh and 28 mesh. Due to the small quantity of +8 mesh magnetics, this fraction was not reprocessed in the laboratory but it could be in practice by adding it to the +28 mesh rougher magnetic fraction.

Attempts to treat total ore were discontinued due to severe dusting but it is thought this circuit would successfully treat dedusted ore as crushed.

Results typical of 6 x 100 and 6 x 200 mesh ore are presented in Flowsheets 4 and 5.

FLOWSHEET 3

TWO STAGE SERIES ROUGHING WITH MAGNETICS REPROCESSING

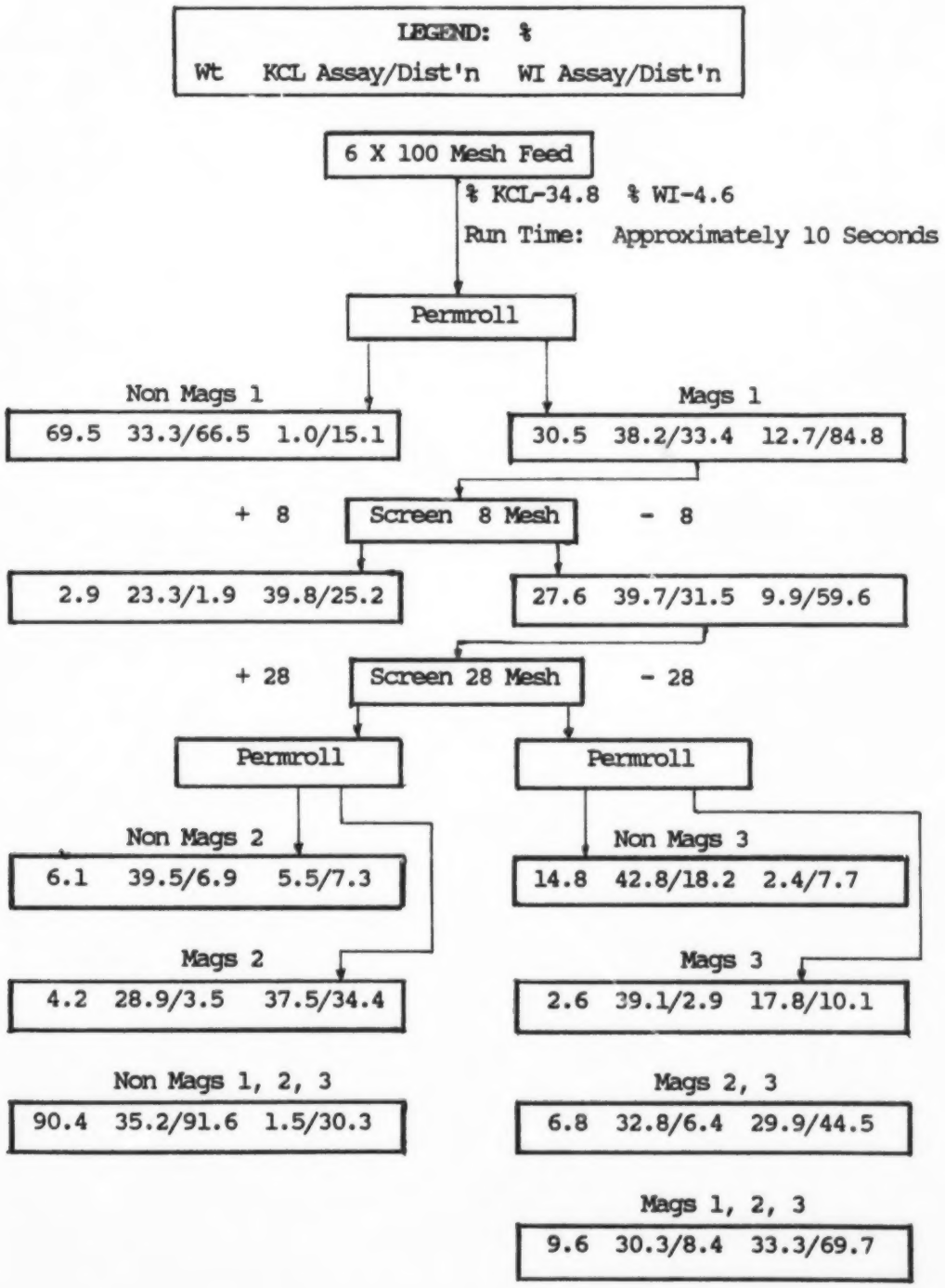


FLOWSHEET 4

TYPICAL RESULTS

SERIES STAGE ROUGHING AND SCREENING MAGNETIC MIDDLINGS

(BEFORE REPROCESSING)

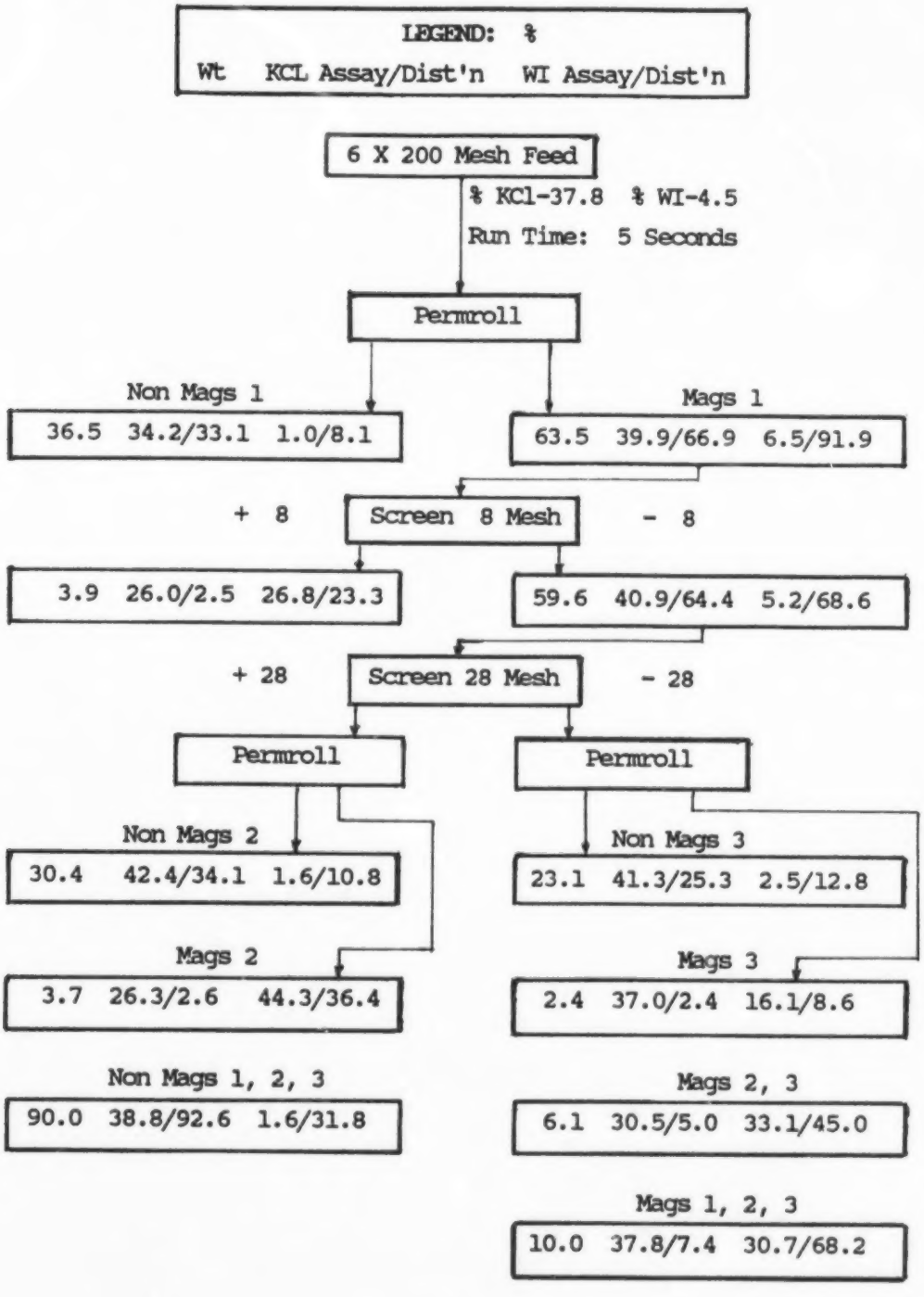


FLOWSHEET 5

TYPICAL RESULTS

SERIES STAGE ROUGHING AND SCREENING MAGNETIC MIDDLINGS

(BEFORE REPROCESSING)



III REPRODUCIBILITY OF RESULTS

Duplicate tests on 6 x 8, 8 x 14 and 14 x 28 mesh size fractions were completed to establish consistency and reproducibility of results with the Permroll. Table IX shows excellent reproducibility in all cases studied. Minor variance does exist for WI (clay) rejection but given the low content relative to that of sylvite (KCl) this is to be expected since several grains of clay reporting into either the magnetics or non-magnetics can affect the ultimate result.

TABLE IX

REPRODUCIBILITY OF RESULTS

Mesh	Magnetics					Non Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
6 x 8	12.9	24.6	40.0	10.8	72.9	87.1	30.2	2.2	89.2	27.1	29.5	7.1
	13.4	23.7	39.9	10.4	75.5	86.6	31.6	2.0	89.6	24.5	30.5	7.1
	13.7	23.4	39.9	10.6	76.9	86.3	31.2	1.9	89.4	23.1	30.1	7.1
	14.2	24.1	37.7	11.2	77.6	85.8	31.5	1.8	88.8	22.4	30.4	6.9
Average	13.5	24.0	39.5	10.8	75.7	86.5	31.1	2.0	89.2	24.3	30.2	7.0
8 x 14	11.7	27.3	31.4	9.3	73.5	88.3	35.3	1.5	90.7	26.5	34.4	5.0
	11.9	27.9	30.3	9.6	73.2	88.1	35.5	1.5	90.4	26.8	34.6	4.9
Average	11.8	27.6	30.8	9.4	73.4	88.2	35.4	1.5	90.5	26.6	34.5	5.0
	9.6	28.1	31.0	7.3	68.7	90.4	37.9	1.5	92.7	31.3	37.0	4.3
	10.5	28.2	27.2	8.0	68.0	89.5	38.0	1.5	92.0	32.0	37.0	4.2
Average	10.0	28.1	29.1	7.6	68.4	89.9	37.9	1.5	92.3	31.6	37.0	4.2
14 x 28	8.3	32.1	23.4	6.4	63.8	91.7	42.5	1.2	93.6	36.2	41.6	3.0
	8.1	33.4	26.7	6.5	66.2	91.7	42.6	1.2	93.6	33.8	41.8	3.3
Average	8.2	32.7	25.0	6.4	65.0	91.7	42.6	1.2	93.6	35.0	41.7	3.1

IV DISCUSSION OF RESULTS

The effectiveness of clay removal magnetically has been positively demonstrated. The versatility of the Permroll is emphasized by each of the five circuits studied, and by the variety of size ranges, each of which can be considered in practical terms. This is important in evolving a lowest cost, most efficient practical circuit.

On the average, clay rejection magnetically can be as high or higher than presently attained in the mill production circuit. Thus, 60 to 70% of the total clay can be removed from the process stream without scrubbing and desliming. Although not specifically studied, it should be possible to recover KCl from the magnetic stream by reprocessing on a weaker magnetic roll. It is thought the deep red-coloured potash initially reporting in the magnetic fraction is not as magnetic as the clay and could be reprocessed to ensure 97 to 98% of the total sylvite (KCl) reporting to the non-magnetic fraction.

Magnetic separation of material finer than 35 mesh is adversely affected by magnetic flocculation (electrostatic effect). This effect can probably be overcome by treatment on weaker magnetic rolls. Effective removal of fine clay could be important to ensure subsequent flotation with no scrubbing or desliming and with reduced slime depressant usage.

Based on heavy liquid tests and analyses of sink material at a specific gravity of 2.46, some 11% KCl and 15% NaCl is occluded in the clay. This suggests the ore value is some 0.5% lower in recoverable sylvite than normal analyses establishes in practice.

Feed rates generally ranged from about 2.5 seconds per kilogram in the case of the more complex circuits to 20 seconds per kilogram in the case of the simple single stage circuit. Because of feed-end and tail-end "feathering" (ie. thinning out effects prevalent at the start and finish of a test), accurate timing was difficult. Time did not allow ten to twenty kilogram continuous runs to establish more accurate throughput data. However, based on the relative times observed, practical tonnages could be as high as 40 tons per hour and as low as 5 tons per hour depending upon the circuit configuration. A pilot plant investigation is recommended to establish practical tonnage capabilities and most economic circuit configuration. Four-inch diameter magnetic rolls should be used rather than the three-inch used in this investigation. This would ensure the best attainable performance and data.

Though not pertinent to this investigation, it is interesting to note the power efficiency of this high intensity magnet roll machine. A practical production unit is powered by a 1/4 HP, 120 volt motor with the equivalent utilized by the vibrating feeder.. Even given a capacity of 10 TPH per unit and power draft even equal to connected horsepower, some 5 HP would process 100 TPH — a very low power requirement per ton in comparison to any other practical unit currently in ore processing use.

V CONCLUSIONS

a) In terms of residual water insoluble content of non-magnetics (equivalent to practical rougher flotation circuit feed), magnetic separation is generally more effective than conventional wet scrubbing-desliming prevalent in current milling practice, however, the effect on subsequent flotation performance requires thorough investigation.

b) Despite magnetic flocculation of fines which inhibits effective separation of water insolubles from the sylvite-halite components (very likely intensified by the high magnetic gradient of the Permroll), near total ore (ie. 6 x 100 or 6 x 200 mesh) can be readily processed. It is likely adequately dedusted ore can be as successfully treated in practice. Additionally, it is thought lower magnetic gradient rolls would effectively process fines. Similar rolls would undoubtedly scavenge liberated feebly magnetic potash from the magnetic fraction to reduce losses of marketable product. Effectiveness of lower magnetic gradient rolls require investigation for these applications.

c) A multi-stage circuit is as effective as a single-stage circuit in terms of water insoluble rejection and KCl retention. The multi-stage circuit has the advantage of significantly increased throughput capability -- by a factor of two to four over the single-stage circuit.

d) A dual stage "roughing" circuit adjusted to yield an acceptable non-magnetic product and a comparatively high volume, low water insoluble content (about 10%) magnetic portion effectively processed "near total ore". Screening of the magnetic portion at 28 mesh and reprocessing the resulting products magnetically rejects 60 to 70% of the water insolubles while retaining in excess of 90% of the sylvite.

   The potential of this circuit should be critically studied on a pilot plant scale to establish viability and throughput.

e) Due to the short processing times for the one kilogram sample lots used in the investigation, any translation into tonnage rates should be deemed indicative only. The novelty of the application reaffirms the need for pilot plant testing to establish throughput rates accurately.

CLAY LIBERATION (TASK 2)

I CLAY CHARACTERISTICS

Dolomite, anhydrite, quartz, illite, chlorite, kaolinite, vermicullite and montmorillonite have been identified in Central Canada Potash water insoluble matter(1). Additionally, two distinct types of clay predominate:

a) a brown clay that generally occurs in massive bands containing illite, kaolinite, montmorillonite, vermicullite, dolomite, anhydrite and quartz.

b) a green clay containing illite, chlorite, kaolinite, dolomite, anhydrite and quartz. This clay is generally dissemated or occluded as fine grains.

Anhydrite and dolomite thought to be the binding agents are more dominant in the green clay. The relative quantities and composition of both types vary. The specific gravity of the green clay has been tentatively established at about 2.3, while the brown clay appears to range between 2.5 and 2.6.

Iron is probably the magnetic component. It is common to both brown and green clays but its association has not been established. An analyses of green clay suggested 0.39% Fe; of the brown clay 1.04% Fe. There is reason to believe some 50% of the total iron in the ore is associated with the water insoluble (clay) component. The remainder is divided between the halite and sylvite, more or less equally.

The average of ten analytical results suggests some 11% KCl and 15% NaCl (as determined from water soluble K and Na) is present in high (+2.46) specific gravity (brown) clay. The balance (74%) is water insoluble matter.

It is thought the water insolubles of Patience Lake member ores exhibit similar characteristics. Project participants' ores fall into this category.

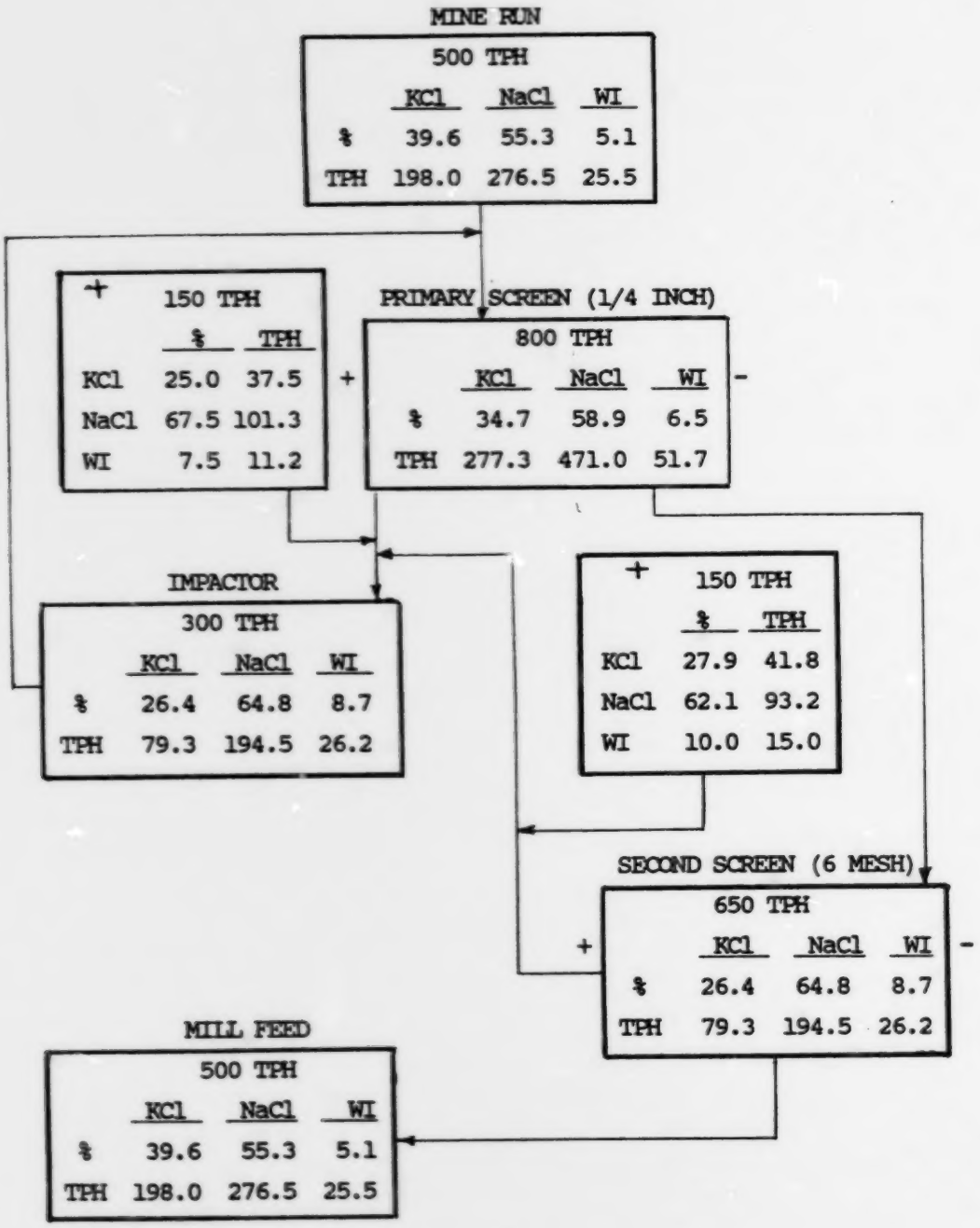
(1) See References, Page 50

FIGURE 1

POSSIBLE MASS BALANCE* FOR MAJOR ORE COMPONENTS

CRUSHING PLANT

(* based on Tables I, XIII and XIV)



II BEHAVIOUR OF CLAY COMPONENTS IN CRUSHING

Figure 1 is a possible mass balance for the crushing plant. It is based on data obtained at various times during this project. The duplication of mine run and mill feed results is coincidental, but this balance illustrates and supports the tendency of the clay to concentrate in the coarser fractions due to its greater resistance to impact crushing than prevails for the halite and sylvite.

Based on this mass balance and the fractional analyses of mine run ore shown in Tables XII and XIII, Table X below re-emphasizes clay hardness, toughness and its dramatic concentration in the secondary screen oversize.

TABLE X

ESTIMATED TONNAGES OF COMPONENTS IN PRIMARY & SECONDARY SCREEN OVERSIZE
Relative to Crushing Plant (+6 Mesh) Mine Ore Input

	Ore	KCl	NaCl	WI
Tons +6 Mesh	303.5	91.5	159.5	16.6
Tons Primary Screen Oversize	150	37.5	101.3	11.2
% Circulating	49.4	41.0	63.5	67.5
Tons Secondary Screen Oversize	150	41.8	93.2	15.0
% Circulating	49.4	45.7	58.4	90.4
Tons Primary & Secondary Screen Oversize	300	79.3	194.5	26.2
% Circulating	98.8	86.7	121.9	157.9

III CLAY LIBERATION CHARACTERISTICS

Tables XI to XVII(C) inclusive show data pertinent to clay liberation. Included are fractional analyses of typical mine run ore, crushing plant primary screen oversize, secondary screen oversize and mill feed. Heavy liquid separation results at 2.05, 2.2 and 2.46 specific gravity are listed. These nominal levels were selected to gain some insight into the behaviour of sylvite and water insolubles. Thus 2.05 floats positively identify sylvite liberation behaviour. A specific gravity of 2.2 distinguishes between the water insoluble and the sylvite-halite components. The 2.2 sink accounts for the bulk of liberated clay, whereas the float concentrates the minor clay-salts middlings and the disseminated clay along with the salts (sylvite and halite). The two clay types are separated quite effectively at a 2.46 specific gravity.

Although variation in the results exists (due most likely to variations in ore composition, notably clay), clay liberation can be significant even in the +1 inch size range.

Considering Figure 1 and Table XIII(A), given ideal clay rejection in the 1 inch to +4 mesh size range (as good as attained by heavy liquid separation at a 2.2 specific gravity), 13.3% of the ore in this size range (representing 3.9% of the KCl, 15.3% of the NaCl and 43.9% of the water insolubles) is accounted for (correspondingly, this represents 1.5% KCl, 7.7% NaCl and 26.7% WI in terms of total ore). Considering brine absorption, the resultant KCl rejection is negligible, whereas the WI rejection is significant. Additionally, the KCl value is upgraded from 33.8% to 37.5%, whereas the WI value is reduced from 6.7% to 4.3%. Table XIII(C) summarizes these observations which are based on Tables XI, XIII(A) and Figure 1.

Time constraints and the intricate variability of ore behaviour to the size reduction process did not permit positive establishment of a definite size where clay liberation occurs. Additionally, impact crushing prevalent in plant practice probably does not represent the ultimate means of optimizing liberation and minimizing clay middlings production which to a degree persist even in the -20 mesh sizes. The obvious absorption of brine by the clay during the formation of the Prairie Evaporite beds also complicates any such study.

Since this investigation was mainly concerned with the practicality of rejecting as much water insoluble matter from the ore as possible at as coarse a size as possible without seriously jeopardizing the sylvite (KCl) component, clay liberation is thought of in these terms. Thus clay liberation is certainly significant in plus 0.375 inch mine run ore given economically practical means for removal. Although attempted with the Permroll, results were not encouraging on primary crusher screen oversize (a nominal 2 inch by 0.375 inch size range). However, positive results were obtained when treating secondary screen oversize (a nominal 0.375 by 6 mesh size range).

TABLE XI

TYPICAL MINE RUN ORE FRACTIONAL ANALYSIS

Inch or Mesh	% Wt	Analyses %			Dist'n %		
		KCl	WI	NaCl	KCl	WI	NaCl
+ 1	14.0	34.1	7.8	57.8	12.2	21.5	14.5
1 x 3/4	5.0	38.8	8.0	53.2	4.9	7.9	4.9
3/4 x 1/2	8.2	33.4	8.1	58.5	6.9	13.1	8.8
1/2 x 3/8	5.5	31.6	6.5	61.9	4.4	7.0	6.2
3/8 x 3M	6.3	31.8	3.9	64.3	5.1	4.8	7.4
3 x 4	7.6	33.4	4.5	62.1	6.4	6.7	8.6
4 x 6	6.7	37.0	3.3	59.7	6.3	4.3	7.3
6 x 8	7.4	38.5	2.6	58.9	7.2	3.8	8.0
8 x 10	7.3	43.4	2.7	53.9	8.0	3.9	7.2
10 x 14	6.2	48.4	2.4	49.2	7.6	2.9	5.6
14 x 20	5.3	48.7	3.0	48.3	6.5	2.9	4.9
20 x 28	4.8	49.8	2.9	47.3	6.0	5.7	4.2
28 x 35	3.6	50.0	3.2	46.8	4.5	2.3	3.1
35 x 48	3.1	50.2	3.5	46.3	3.9	2.1	2.6
48 x 65	2.2	50.6	3.8	45.6	2.8	1.7	1.8
65 x 100	2.0	48.5	4.5	47.0	2.4	1.8	1.7
100 x 150	1.7	45.4	5.9	48.7	2.0	2.1	1.5
150 x 200	0.9	41.7	6.4	51.9	0.9	1.1	0.9
- 200	2.2	35.0	10.1	54.9	2.0	4.4	0.8
Total	100.0	39.6	5.1	55.3	100.0	100.0	100.0

TABLE XII

TYPICAL PRIMARY SCREEN OVERSIZE FRACTIONAL ANALYSES
(Crushing Plant)

Inch or Mesh	% Wt	Analyses %		Dist'n %	
		KCl	WI	KCl	WI
+ 1	11.1	24.3	4.1	10.8	6.1
1 x 3/4	8.9	27.7	8.5	9.9	10.1
3/4 x 1/2	21.9	26.1	8.9	22.9	26.1
1/2 x 3/8	24.1	21.5	8.7	20.7	28.0
3/8 x 3M	22.5	23.0	7.7	20.7	23.2
3 x 6	5.9	30.1	5.3	7.1	4.2
- 6	5.6	33.7	3.1	7.9	2.3
Total	100.0	25.0	7.5	100.0	100.0

TYPICAL SECONDARY SCREEN OVERSIZE FRACTIONAL ANALYSES
(Crushing Plant)

Mesh	% Wt	Analyses %		Dist'n %	
		KCl	WI	KCl	WI
+ 3	14.9	27.6	9.8	14.8	14.6
3 x 6	63.7	26.7	11.4	60.4	72.9
- 6	21.4	32.4	5.8	24.8	12.5
Total	100.0	27.9	10.0	100.0	100.0

TABLE XIII(A)

HEAVY LIQUID SEPARATION

Mine Run Ore
Specific Gravity 2.20

+1 Inch	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	83.9	36.7	6.2	94.7	48.6
Sink	16.1	6.2	19.6	5.3	51.4
Total	100.0	29.1	12.7	100.0	100.0
-1 Inch +0.75 Inch					
Float	90.2	41.2	3.9	97.8	59.4
Sink	9.8	8.4	24.5	2.2	40.6
Total	100.0	38.0	5.9	100.0	100.0
-0.75 Inch +0.5 Inch					
Float	80.9	36.4	4.9	94.5	51.2
Sink	19.1	9.0	19.8	5.5	48.8
Total	100.0	31.2	7.7	100.0	100.0
-0.5 Inch +3 Mesh					
Float	75.7	31.8	4.3	90.0	36.8
Sink	24.3	11.0	23.0	10.0	63.2
Total	100.0	26.7	8.8	100.0	100.0
-3 Mesh +4 Mesh					
Float	88.9	36.5	2.9	96.6	51.5
Sink	11.1	10.2	21.9	3.4	48.5
Total	100.0	33.6	5.0	100.0	100.0

TABLE XIII(B)

HEAVY LIQUID SEPARATION

Mine Run Ore
Specific Gravity 2.05

+1 Inch	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	4.9	71.6	1.4	9.6	8.8
Sink	95.1	33.7	7.5	90.4	91.2
Total	100.0	36.6	7.8	100.0	100.0
-1 Inch +0.75 Inch					
Float	8.8	62.4	4.1	13.6	5.7
Sink	91.2	38.3	6.5	86.4	94.3
Total	100.0	40.4	6.3	100.0	100.0
-0.75 Inch +0.5 Inch					
Float	7.0	66.3	1.6	17.2	1.7
Sink	93.0	24.0	7.0	82.8	98.3
Total	100.0	27.0	6.6	100.0	100.0
-0.5 Inch +3 Mesh					
Float	11.2	79.1	1.2	33.3	1.4
Sink	88.8	20.0	10.7	66.7	98.6
Total	100.0	26.6	9.6	100.0	100.0
-3 Mesh +4 Mesh					
Float	23.1	85.5	1.3	61.9	4.8
Sink	76.9	15.8	7.7	38.1	95.2
Total	100.0	31.9	6.2	100.0	100.0

TABLE XIII(C)

ESTIMATE OF POSSIBLE WI REJECTION FROM MINE RUN ORE
(500 Tons Per Hour)

	Inches or Mesh Size						Analyses
	+1.0	+0.75	+0.50	+3 M	+4 M	Total	%
Mine Ore (tons)	70.00	25.00	41.00	59.00	38.00	233.00	—
KCl "	24.08	9.70	13.69	18.71	12.69	78.87	33.8
NaCl "	40.46	13.30	23.99	37.25	23.60	138.60	59.5
WI "	5.46	2.00	3.32	3.04	1.71	15.53	6.7
Reject "	2.25	2.45	7.83	14.33	4.22	31.08	—
KCl "	0.14	0.21	0.70	1.58	0.43	3.06	9.8
NaCl "	1.67	1.64	5.58	9.45	2.86	21.20	67.8
WI "	0.44	0.60	1.55	3.30	0.93	6.82	21.9
Residue "	67.75	22.55	33.17	44.67	33.78	201.92	—
KCl "	23.94	9.49	12.99	17.13	12.26	75.81	37.5
NaCl "	38.79	11.66	18.41	27.80	20.74	117.40	58.2
WI "	5.02	1.40	1.77	-0.26	0.78	8.71	4.3

	% Rejected In Size Range	Total Ore Input
Ore	13.3	6.2
KCl	3.9	1.5
NaCl	15.3	7.7
WI	43.9	26.7

TABLE XIV(A)

HEAVY LIQUID SEPARATION

Primary Screen Oversize
Specific Gravity 2.22

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+1 Inch	No separation (ie. all "float")				
-1 Inch +0.75 Inch					
Float	93.6	32.3	4.3	97.9	81.8
Sink	6.4	10.4	24.5	2.1	28.2
Total	100.0	30.9	5.5	100.0	100.0
-0.75 Inch +0.5 Inch					
Float	86.1	28.4	4.3	92.7	38.1
Sink	13.9	13.8	43.2	7.3	61.9
Total	100.0	26.3	9.7	100.0	100.0
-0.5 Inch +0.375 Inch					
Float	85.6	26.3	3.7	92.7	35.1
Sink	14.4	12.3	40.8	7.3	64.9
Total	100.0	24.3	9.1	100.0	100.0
-0.375 Inch +3 Mesh					
Float	82.7	24.9	3.8	91.5	29.7
Sink	17.3	11.0	42.9	8.5	70.3
Total	100.0	22.5	10.6	100.0	100.0
-3 Mesh +6 Mesh					
Float	88.0	33.8	2.2	94.8	27.8
Sink	12.0	12.3	41.6	5.2	72.2
Total	100.0	28.5	6.9	100.0	100.0

TABLE XIV(B)

HEAVY LIQUID SEPARATION

Primary Screen Oversize
Specific Gravity 2.46

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+1 Inch	No separation (ie. all "float")				
-1 Inch +0.75 Inch					
Float	100.0	30.9	5.5	100.0	100.0
-0.75 Inch +0.5 Inch					
Float	95.9	27.4	9.7	96.3	93.0
Sink	4.1	12.9	73.0	3.7	7.0
Total	100.0	26.3	9.7	100.0	100.0
-0.5 Inch +0.375 Inch					
Float	98.5	24.5	8.1	99.4	87.8
Sink	1.5	9.7	73.8	0.6	12.2
Total	100.0	24.3	9.0	100.0	100.0
-0.375 Inch +3 Mesh					
Float	97.0	22.9	8.6	98.7	78.9
Sink	3.0	10.0	74.3	1.3	21.1
Total	100.0	22.5	10.5	100.0	100.0
-3 Mesh +6 Mesh					
Float	97.6	29.0	5.3	99.3	75.1
Sink	2.4	8.8	71.8	0.7	24.9
Total	100.0	28.5	6.9	100.0	100.0

TABLE XIV(C)

HEAVY LIQUID SEPARATION

Primary Screen Oversize
Specific Gravity 2.05

+1 Inch	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	100.0	24.3	4.1	100.0	100.0
-1 Inch +0.75 Inch					
Float	16.0	65.0	1.1	33.5	3.2
Sink	84.0	24.4	6.4	66.5	96.8
Total	100.0	32.2	4.2	100.0	100.0
-0.75 Inch +0.5 Inch					
Float	10.7	67.5	2.1	27.4	2.3
Sink	89.3	21.4	10.6	72.6	97.7
Total	100.0	26.3	9.7	100.0	100.0
-0.5 Inch +0.375 Inch					
Float	10.6	72.6	1.6	31.6	1.9
Sink	89.4	18.6	9.9	68.4	98.1
Total	100.0	24.3	9.0	100.0	100.0
-0.375 Inch +3 Mesh					
Float	14.8	75.2	1.4	49.5	2.0
Sink	85.2	13.3	12.1	50.5	98.0
Total	100.0	22.5	10.5	100.0	100.0
-3 Mesh +6 Mesh					
Float	24.2	84.7	1.6	71.8	5.6
Sink	75.8	10.6	8.6	28.2	94.4
Total	100.0	28.5	6.9	100.0	100.0

TABLE XV(A)

HEAVY LIQUID SEPARATION

Secondary Screen Oversize (Sample 1)
Specific Gravity 2.20

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+3 Mesh					
Float	84.2	23.8	2.9	91.3	27.1
Sink	15.8	12.1	41.0	8.7	72.9
Total	100.0	21.9	8.8	100.0	100.0
3 x 4 Mesh					
Float	85.4	27.0	2.4	92.4	25.5
Sink	14.6	13.0	41.4	7.6	74.5
Total	100.0	25.0	8.1	100.0	100.0
4 x 6 Mesh					
Float	83.5	29.9	1.7	90.7	16.4
Sink	16.5	15.8	46.7	9.3	83.6
Total	100.0	27.6	9.1	100.0	100.0
-6 Mesh					
Float	85.1	34.1	1.6	93.9	20.3
Sink	14.9	12.7	37.2	6.1	79.7
Total	100.0	31.0	6.9	100.0	100.0
Overall					
Float	84.5	28.9	2.1	91.9	21.4
Sink	15.5	14.5	42.4	8.1	21.4
Total	100.0	26.5	8.4	100.0	100.0

TABLE XV(B)

HEAVY LIQUID SEPARATION

Secondary Screen Oversize (Sample 1)
Specific Gravity 2.03

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+3 Mesh					
Float	12.7	84.1	0.9	49.3	1.3
Sink	87.3	12.8	9.5	50.7	98.7
Total	100.0	21.9	8.8	100.0	100.0
3 x 4 Mesh					
Float	18.6	82.9	1.0	61.1	2.3
Sink	81.4	11.9	9.7	38.9	97.7
Total	100.0	25.0	8.1	100.0	100.0
4 x 6 Mesh					
Float	21.2	91.4	1.2	70.6	2.8
Sink	78.8	10.3	11.3	29.4	97.2
Total	100.0	27.6	9.1	100.0	100.0
-6 Mesh					
Float	26.3	93.8	1.3	80.7	5.0
Sink	73.7	8.2	8.9	19.3	95.0
Total	100.0	31.0	6.9	100.0	100.0
Overall					
Float	20.0	89.0	1.1	67.1	3.2
Sink	80.0	10.9	10.2	32.9	96.8
Total	100.0	26.5	8.4	100.0	100.0

TABLE XVI(A)

HEAVY LIQUID SEPARATION

Secondary Screen Oversize (Sample 2)
Specific Gravity 2.20

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+3 Mesh					
Float	82.2	30.8	3.7	91.1	27.9
Sink	17.8	14.0	44.3	8.9	72.1
Total	100.0	27.8	10.9	100.0	100.0
3 x 6 Mesh (includes +4 Mesh)					
Float	80.6	30.3	2.7	89.6	19.4
Sink	19.4	14.7	46.0	10.4	80.6
Total	100.0	27.3	11.1	100.0	100.0
-6 Mesh					
Float	84.5	33.3	2.3	92.2	22.1
Sink	15.6	15.2	44.6	7.8	78.9
Total	100.0	30.5	8.9	100.0	100.0
Overall					
Float	82.4	31.5	2.9	90.9	23.2
Sink	17.6	14.6	45.0	9.1	76.8
Total	100.0	28.5	10.8	100.0	100.0

TABLE XVI(B)

HEAVY LIQUID SEPARATION

Secondary Screen Oversize (Sample 2)
Specific Gravity 2.46

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+3 Mesh					
Float	96.7	28.3	8.7	98.5	76.6
Sink	3.3	12.9	77.5	1.5	23.4
Total	100.0	27.8	10.9	100.0	100.0
3 x 6 Mesh (includes +4 Mesh)					
Float	96.0	27.9	8.3	98.4	71.8
Sink	4.0	11.3	78.3	1.6	28.2
Total	100.0	27.3	11.1	100.0	100.0
-6 Mesh					
Float	96.9	31.1	6.7	98.9	73.2
Sink	3.1	10.9	77.3	1.1	26.8
Total	100.0	30.5	8.9	100.0	100.0
Overall					
Float	96.5	29.1	7.9	98.6	73.9
Sink	3.5	11.7	77.7	1.4	26.1
Total	100.0	28.5	10.8	100.0	100.0

TABLE XVI(C)

HEAVY LIQUID SEPARATION

Secondary Screen Oversize (Sample 2)
Specific Gravity 2.05

	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
+3 Mesh					
Float	20.8	70.6	1.4	52.7	2.7
Sink	79.2	16.6	13.4	47.3	97.3
Total	100.0	27.8	10.9	100.0	100.0
3 x 6 Mesh (includes +4 Mesh)					
Float	21.9	78.9	1.5	63.5	3.0
Sink	78.1	12.7	13.8	36.5	97.0
Total	100.0	27.3	11.1	100.0	100.0
-6 Mesh					
Float	27.4	85.2	1.4	76.5	4.2
Sink	72.6	10.0	12.1	23.5	95.8
Total	100.0	30.5	8.9	100.0	100.0
Overall					
Float	23.4	78.8	1.4	64.6	3.2
Sink	76.6	13.1	13.1	35.4	96.7
Total	100.0	28.5	10.8	100.0	100.0

TABLE XVII(A)

HEAVY LIQUID SEPARATION

OCP Mill Feed
Specific Gravity 2.22

+6 Mesh	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	90.9	30.7	1.6	96.0	28.6
Sink	9.1	12.8	38.6	4.0	71.4
Total	100.0	29.1	4.9	100.0	100.0
6 x 8 Mesh					
Float	92.4	37.7	1.8	96.9	36.1
Sink	7.6	14.6	39.4	3.1	63.9
Total	100.0	35.9	4.7	100.0	100.0
8 x 10 Mesh					
Float	93.9	40.3	1.6	97.8	39.1
Sink	6.1	14.0	39.4	2.2	60.9
Total	100.0	38.7	3.9	100.0	100.0
10 x 14 Mesh					
Float	94.5	44.0	1.4	98.4	38.2
Sink	5.5	12.6	38.4	1.6	61.8
Total	100.0	42.3	3.4	100.0	100.0
14 x 20 Mesh					
Float	95.8	46.2	1.4	98.8	41.5
Sink	4.2	12.5	43.7	1.2	58.5
Total	100.0	44.8	3.1	100.0	100.0
20 x 28 Mesh					
Float	95.5	47.6	1.4	99.0	40.7
Sink	4.5	10.8	41.9	1.0	59.3
Total	100.0	46.0	3.2	100.0	100.0

TABLE XVII(B)

HEAVY LIQUID SEPARATION

OCP Mill Feed
Specific Gravity 2.46

+6 Mesh	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	98.3	29.4	3.7	99.3	73.5
Sink	1.7	11.9	76.5	0.7	26.5
Total	100.0	29.1	4.9	100.0	100.0
6 x 8 Mesh					
Float	98.7	36.2	3.8	99.6	79.5
Sink	1.3	10.6	73.8	0.4	20.5
Total	100.0	35.9	4.7	100.0	100.0
8 x 10 Mesh					
Float	98.8	39.1	3.1	99.7	77.7
Sink	1.2	10.2	73.6	0.3	22.3
Total	100.0	38.7	3.9	100.0	100.0
10 x 14 Mesh					
Float	98.8	42.7	2.6	99.8	74.5
Sink	1.2	9.7	72.5	0.2	25.5
Total	100.0	42.3	3.4	100.0	100.0
14 x 20 Mesh					
Float	98.7	45.2	2.2	99.7	70.0
Sink	1.3	9.6	72.5	0.3	30.0
Total	100.0	44.8	3.1	100.0	100.0
20 x 28 Mesh					
Float	98.3	46.6	2.0	99.7	62.1
Sink	1.7	9.3	70.9	0.3	37.9
Total	100.0	46.0	3.2	100.0	100.0

TABLE XVII(C)

HEAVY LIQUID SEPARATION

CCP Mill Feed
Specific Gravity 2.05

+6 Mesh	% Wt	Analyses % KCl	Analyses % WI	Dist'n % KCl	Dist'n % WI
Float	24.8	86.7	0.9	74.0	4.5
Sink	75.2	10.1	6.3	26.0	95.5
Total	100.0	29.1	4.9	100.0	100.0
6 x 8 Mesh					
Float	33.0	88.8	1.0	81.5	7.0
Sink	67.0	9.9	5.2	19.5	93.0
Total	100.0	35.9	4.7	100.0	100.0
8 x 10 Mesh					
Float	37.8	91.8	1.1	89.5	10.6
Sink	62.2	6.5	5.7	10.5	89.4
Total	100.0	38.7	3.9	100.0	100.0
10 x 14 Mesh					
Float	42.5	93.0	1.0	93.6	12.4
Sink	57.5	4.7	5.2	6.4	87.6
Total	100.0	42.3	3.4	100.0	100.0
14 x 20 Mesh					
Float	46.2	92.6	1.1	95.6	16.2
Sink	53.8	3.6	4.9	4.4	83.8
Total	100.0	44.8	3.1	100.0	100.0
20 x 28 Mesh					
Float	46.4	95.4	1.1	96.3	16.0
Sink	53.6	3.2	5.0	3.7	84.0
Total	100.0	46.0	3.2	100.0	100.0

IV MAGNETIC SEPARATION OF SECONDARY SCREEN OVERSIZE

Although further investigation is required, preferrably on a continuous pilot plant scale to ensure exposure to all possible occurring variations, meaningful magnetic separation of this product appears possible. Rejection of water insolubles in the magnetics ranges between 60 and 70% with WI content of the non-magnetics in the 2.5% to 3.5% range. Heavy liquid separations at a 2.2 specific gravity show a 2.1% to a 2.9% WI in the sink confirming the effectiveness of magnetic separating [see Tables XV(A) and XVI(A)]

Considering Figure 1, the mass balance pertinent to the Central Canada Potash crushing plant, it is seen that the secondary screen oversize represents some 21% of the KCl carried by mine run ore, 34% of the NaCl and 59% of the water insoluble matter. If 60% rejection of the water insoluble is averaged by magnetic separation, nine tons would be rejected along with 3.3 tons of KCl. (Allowance for absorbed KCl and NaCl suggests 11.8 tons would be rejected as water insoluble matter of which almost one ton would be KCl). Thus the KCl loss would equate to about 1.2% of the mill feed which would average 39.5% KCl and 3.3% water insoluble -- a very notable reduction of this detrimental component.

Current available information does not facilitate a ready prediction of the impact clay removal would have on the subsequent operation of the crushing plant but it is likely the circulating load would decrease by 8 to 10% of the normal operating level. This in itself would be very significant. Benefits would likely also accrue in the subsequent wet milling circuits.

V DISCUSSION OF RESULTS

Water insoluble (clay) rejection magnetically generally falls between 60 and 70% in typical mill feed. This criteria was used as the guideline for acceptable liberation in the coarser ore size ranges (+1 inch to 6 mesh). Although gravity separations show 0.75 inch x 0.5 inch ore fits this guideline, magnetic separation above 0.375 inches proved indifferent with the laboratory Permroll. It is likely a larger diameter roll would have yielded more positive results, however, separations on 0.375 inch x 6 mesh crushing plant material were definitely positive. Practical application of this technology could be beneficial to the milling process but pilot plant testing is required.

VI CONCLUSIONS

a) Sufficient clay liberation exists in all coarser ore fractions (+1 inch x 6 mesh) to warrant serious consideration for rejecting this contaminant. Sylvite (KCl) losses would be minimal (in the order of 2% of the total input). This could probably be scavenged in a separate circuit if economically justified (ie. the value of the sylvite discarded would have to be examined against the cost of disintegrating the clay and the economic effect of the resultant fines on the milling process).

b) The 3-inch diameter laboratory Permroll was ineffective in removing clay from +3 mesh material, hence other means must be considered for treating the +1 inch x 3 mesh ore fraction. A larger diameter high intensity magnetic roll might prove suitable.

c) It has been demonstrated that nominal 0.375 inch x 6 mesh material (crushing plant secondary screen oversize) is amenable to magnetic separation with clay rejection in the 60 to 70% range and sylvite retention exceeding 90%. These results could readily be improved by minimizing the production of clay-salts middlings. Cursory knowledge of practical Permroll units suggests the applicability of this technology. Pilot plant testing is essential to confirm this.

PARTICIPANTS' ORES (TASK 3)

Four project participants' ores were tested as these were made available. In some cases, participant personnel executed the testing themselves. Due to time constraints, no in-depth studies could be undertaken but, generally, the flowsheets developed for Central Canada Potash ore are readily adaptable to the treatment of ores originating from the Patience Lake member. Further investigation by individual participants would dictate the best application.

Of noteworthy interest was the cursory exposure to ore with abnormally high clay content (16 to 17%). The results reinforce the adaptability and versatility of the Permroll for clay removal from sylvite-halite ores. Additionally, given similar brine absorption into the clay as suggested in the case of CCP ore, some 15% of the total KCl content is thus associated with the high clay. This suggests sylvite (KCl) retention in the non magnetic fraction cannot appreciably exceed 80% (see Table XVIII, Ore C, Sample A-2A).

Test results are shown in Table XVIII.

TABLE XVIII

PRELIMINARY RESULTS ON PROJECT PARTICIPANTS' ORES

Size/Mesh	Magnetics					Non-Magnetics					Head	
		Analyses %		Dist'n %			Analyses %		Dist'n %			
Ore A	% Wt	KCl	WI	KCl	WI	% Wt	KCl	WI	KCl	WI	KCl	WI
4 x 8	6.1	27.2	27.0	4.2	63.1	93.9	40.2	3.0	95.8	36.9	39.4	4.5
8 x 28	4.7	32.7	28.0	3.3	40.8	95.3	47.0	2.0	96.7	59.2	46.3	3.2
10 x 28	8.8	34.5	22.9	6.3	63.0	91.2	49.4	1.3	93.7	37.0	48.1	3.2
28 x 65	4.3	36.4	28.6	3.1	38.0	95.7	51.1	2.1	96.9	62.0	50.5	3.2
8 x 35	7.6	35.6	24.0	5.7	58.5	92.4	48.1	1.4	94.3	41.5	47.2	3.1
35 x 65	5.3	38.1	27.0	4.0	44.3	94.7	50.9	1.9	96.0	55.1	50.2	3.2
Ore B												
8 x 100	13.3	20.4	27.7	9.9	62.0	86.7	28.4	2.6	90.1	38.0	27.3	5.9
6 x 14	11.1	28.9	29.8	8.1	75.6	88.9	41.3	1.2	91.9	24.4	39.9	4.4
14 x 28	11.7	35.2	25.4	9.5	80.8	88.3	44.3	0.8	90.5	19.2	43.2	3.7
28 x 48	15.0	41.8	18.6	14.1	70.1	85.0	45.0	1.4	85.9	29.9	44.5	4.0
48 x 65	14.8	41.9	14.9	13.9	50.6	85.2	45.3	2.5	86.1	49.4	44.0	4.3
- 65	16.4	37.4	11.0	15.5	24.1	83.6	40.0	6.8	83.6	40.0	39.5	7.5
Ore C												
A-2	44.7	22.3	31.7	40.4	88.0	55.3	26.6	3.5	59.6	12.0	24.7	16.1
A-2A-35M	29.5	15.5	50.5	20.7	85.8	70.5	24.8	3.5	79.3	14.2	22.0	17.4
1-B	31.1	31.0	14.8	28.6	76.1	68.9	34.9	2.1	71.4	23.9	33.7	6.1
1A-B	16.7	27.6	43.3	13.6	80.6	83.3	35.1	2.1	86.4	19.4	33.8	9.0
Ore D												
.5" x .25"	3.7	15.1	48.8	2.0	15.0	96.3	28.0	10.6	98.0	84.9	27.4	12.0
.25" x 4"	11.9	15.0	50.8	7.0	51.7	88.1	27.0	6.4	93.0	48.3	25.5	11.7
4 x 5	13.9	15.9	52.4	8.4	62.8	86.1	28.1	5.0	91.6	37.2	26.4	11.6
5 x 6	13.9	16.2	49.7	8.6	71.2	86.1	28.0	3.3	91.4	28.8	26.3	9.7
6 x 8	13.3	22.0	38.1	9.0	78.4	86.7	34.4	1.6	91.0	21.6	32.5	6.5
10 x 20	14.0	29.0	29.5	10.5	84.8	86.0	40.3	0.9	89.5	15.2	38.6	4.9
20 x 48	11.4	33.3	30.2	9.1	80.7	88.6	42.9	0.9	90.9	19.3	48.3	4.4
48 x 100	15.5	35.7	22.7	13.6	73.4	84.5	40.5	1.5	86.4	26.6	40.5	4.8

HALITE ACTIVATION (TASK 4)

I CONCEPT

The application of magnetic separation technology in the treatment of potash ore would be rendered very desirable if some halite could be induced to follow the magnetic clay in preference to sylvite (ie. selectively). Alternately, sylvite activation could be acceptable following magnetic clay removal providing the resultant non magnetics were sufficiently free of sylvite. Consequently, preliminary work was undertaken supplementary to clay removal magnetically.

Both sylvite and halite are similarly and highly diamagnetic (the respective magnetic susceptibilities being -39.0×10^{-6} cgs and -30.3×10^{-6} cgs respectively). Highly paramagnetic ($+10,000 \times 10^{-6}$ cgs), water soluble salts were used on a "hit and miss" basis in an effort to alter the magnetic properties. These included manganese, iron and cobalt dual and triple valence salts. Lead acetate was included on the strength of its "activator" role in the discontinued halite flotation process.

II TEST PROCEDURE

Two lots of ore pre-sized to 14 x 28 mesh and 28 x 48 mesh, respectively, were declayed. Each totalled 16 to 17 kilograms to ensure sufficient ore with similar characteristics for subsequent test series. The 14 x 28 mesh ore only was used in the testing. Time did not permit any investigation on the 28 x 48 mesh fraction. Five hundred (500) gram test lots were used.

Chemical addition was generally as a 1% water solution injected into an aerated plastic column which was used to condition (mix) the chemical and ore. Conditioning lasted 30 minutes after the relative humidity of the escaping air stream fell below 10%. The conditioned ore was transferred into the Permroll feed hopper directly.

To ensure that results reflected the effect of pretreatment, all machine controls were "zeroed" for untreated ore following which they remained unaltered and untouched except for the power supply to the system. Eight of the twenty tests in the series were aerated at 160°F.

In another test series, ferric chloride ($FeCl_3$) addition ranged from the equivalent of one pound per ton to twenty pounds per ton. As $FeCl_3$ dosage increased, solution concentration was appropriately increased to maintain the same solution volume in all cases. Ferric chloride was chosen in this case because treated ore displayed very strong electrostatic effects.

III TEST RESULTS AND DISCUSSION

Table XX lists the results obtained with various paramagnetic salts at a one pound per ton dosage rate. These show minor activation of both sylvite and halite, although sylvite activation appears to be emphasized in all cases. Some minor selectivity as indicated by the NaCl:KCl ratios for the magnetic and non-magnetic fractions are noted. This preliminary study yielded no startling results but it appears that influencing the behaviour of sylvite and halite may be possible. Only further, diligent and methodical investigation can establish this.

The indicated effect of heat is interesting. In all eight cases halite rejection improved as shown by the NaCl:KCl ratios of the magnetics. Recoveries of both components, however, declined except in the case of ferric chloride ($FeCl_3$) and manganous acetate (MnAc). Cobaltous sulphate ($CoSO_4$) indicated some affinity for activating halite. Time constraints prevented obtaining more conclusive evidence.

The effect of increasing dosages of paramagnetic salts ($FeCl_3$) on the activation and selectivity process is presented in Table XIX. Results show selectivity in terms of halite rejection into the magnetics improves slightly with increasing $FeCl_3$ dosage. The activation of both sylvite and halite does increase significantly.

TABLE XIX

HALITE ACTIVATION — EFFECT OF INCREASING $FeCl_3$ DOSAGE

	Magnetics						Non Magnetics								
	Analyses %				Dist'n %		Analyses %				Dist'n %		Head %		
#/T	% Wt	KCl	NaCl	Na/K	KCl	NaCl	% Wt	KCl	NaCl	Na/K	KCl	NaCl	KCl	NaCl	Na/K
1	4.8	41.4	52.6	1.27	5.0	4.3	95.2	39.3	59.2	1.51	95.0	95.7	39.4	58.9	1.49
1	4.3	41.9	51.7	1.23	4.5	3.8	95.7	39.6	59.0	1.49	95.5	96.2	39.7	58.7	1.48
5	8.2	44.3	51.5	1.16	9.4	7.0	91.8	38.3	60.3	1.57	90.6	93.0	38.8	59.6	1.54
10	14.9	44.6	52.4	1.17	16.7	13.3	85.1	38.9	59.8	1.54	83.3	86.7	39.7	58.1	1.48
20	24.1	44.6	53.2	1.19	27.2	21.8	75.9	38.0	60.7	1.60	72.8	78.2	39.6	58.9	1.49

Since the paramagnetic salts did not appear to affect the behaviour of the residual water insoluble material, this component was omitted from this presentation.

TABLE XX

HALITE ACTIVATION — EFFECT OF MAGNETIC ORGANIC SALTS

Salt	Magnetics						Non Magnetics						Head %		
		Analyses %			Dis'n %			Analyses %			Dist'n %				
	% Wt	KCl	NaCl	Na/K	KCl	NaCl	% Wt	KCl	NaCl	Na/K	KCl	NaCl	KCl	NaCl	Na/K
0	3.1	38.6	51.6	1.34	3.1	2.7	96.9	39.2	59.4	1.52	96.9	97.3	39.2	59.1	1.51
PbAc	3.1	40.3	49.4	1.23	3.1	2.6	96.9	40.0	58.6	1.46	96.9	97.4	40.0	58.3	1.46
$MnCl_2$	3.4	40.1	51.1	1.27	3.4	3.0	96.6	39.5	59.0	1.49	96.6	97.0	39.5	58.8	1.49
$MnSO_4$	3.8	40.1	51.1	1.27	3.9	3.3	96.2	39.3	59.2	1.51	96.1	96.7	39.3	58.9	1.50
MnAc	3.2	41.3	51.3	1.24	3.3	2.8	96.8	39.7	58.8	1.48	96.7	97.2	39.8	58.5	1.47
$MnBr_2$	3.3	40.6	52.1	1.28	3.5	2.9	96.7	38.5	60.0	1.56	96.5	97.1	38.6	59.7	1.55
$FeCl_2$	3.3	40.2	52.5	1.31	3.4	2.9	96.7	38.7	59.8	1.55	96.6	97.1	38.8	59.5	1.53
$CoCl_3$	3.1	41.6	50.2	1.21	3.3	2.6	96.9	38.6	59.9	1.55	96.7	97.4	38.7	59.6	1.54
$Fe(NH_4)_2(SO_4)_2 \cdot 6\ H_2O$	3.6	41.1	52.0	1.27	3.8	3.3	96.4	39.4	59.1	1.50	96.2	96.7	39.5	58.8	1.49
$FeSO_4 \cdot 7\ H_2O$	3.7	41.6	51.9	1.25	3.9	3.3	96.3	39.3	59.2	1.51	96.1	96.7	39.4	58.9	1.49
$FeNH_4(SO_4)_2 \cdot 12\ H_2O$	4.0	40.6	51.9	1.29	4.1	3.5	96.0	39.7	58.9	1.48	95.9	96.5	39.2	59.0	1.51
$FeCl_2 \cdot 4\ H_2O$	4.0	41.6	50.8	1.22	4.2	3.4	96.0	39.1	59.3	1.52	95.8	96.6	39.2	59.0	1.51
$FeCl_3$	3.3	42.4	50.4	1.19	3.6	2.8	96.7	39.3	59.4	1.51	96.4	97.2	39.4	59.1	1.50
$FeCl_2 \cdot 4\ H_2O$	3.2	42.1	50.7	1.20	3.4	2.8	96.8	40.0	58.8	1.47	96.6	97.2	40.1	58.5	1.46
$FeNH_4(SO_4)_2 \cdot 12\ H_2O$	2.6	43.3	48.9	1.13	2.9	2.2	97.4	39.3	59.3	1.51	97.1	97.8	39.4	59.0	1.50
$CoSO_4$	2.6	42.5	48.7	1.15	2.8	5.7	97.4	39.9	58.7	1.47	97.2	94.3	40.0	58.4	1.46
$Fe(NH_4)_2(SO_4)_2 \cdot 6\ H_2O$	2.3	42.0	48.6	1.16	2.4	1.9	97.7	40.2	58.4	1.45	97.6	98.1	40.2	58.2	1.45
MnAc	3.2	42.8	49.2	1.14	3.4	2.7	96.8	39.7	58.9	1.48	96.6	97.3	39.8	58.6	1.47
$FeSO_4 \cdot 7\ H_2O$	2.7	41.5	50.5	1.22	2.8	2.3	97.3	39.7	59.0	1.49	97.2	97.7	39.7	58.8	1.48
$MnBr_2$	2.2	42.5	48.3	1.14	2.4	1.8	97.8	39.6	58.9	1.49	97.6	98.2	39.7	58.6	1.48

Notes: Dosage - #/T ore dehydrated equivalent.
Na/K denotes NaCl:KCl ratio.
All Permroll operating control settings unchanged for series.
All salts exhibited electrostatic properties - $FeCl_3$ very strong.
Results below line - aerated at 160°F in presence of salts.

IV CONCLUSIONS

These preliminary results suggest further probing into the possibilities of halite activation are warranted. The novelty of the endeavour coupled with the practical significance given any degree of success should be a sufficient motivating force.

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APPENDIX I

THE BATEMAN PERMROLL

This is a very simple, but versatile, and precise unit. In this application it proved capable of effectively handling materials of a wide size range -- from 3 mesh to 200 mesh in a variety of size combinations as well as a wide range of throughputs.

It is a high intensity, high gradient magnetic variable-speed roll, with a nominal 3 inch diameter and a 4 inch wide face to which feed is metered by a variable amplitude vibrating feeder. Feed is pre-metered to the vibrating trough from a bin with an adjustable gate. This was a beltless unit so the feed was introduced directly onto the roll surface. A rotating brush ensured no carry-over of magnetics, but in this application was deemed to be superfluous since the weakly magnetic clay generally left the roll surface in the two to two-thirty o'clock position.

Four operating variables establish separating effectiveness, namely:

(1) roll speed,
(2) feeder vibration amplitude,
(3) feed rate (ie. feed gate setting),
(4) splitter blade positioning.

A discussion of the influence and importance of these variables follows. It is based on observations pertinent to this investigation and may not conform with other established concepts.

I ROLL SPEED

This is infinitely variable from 0 to in excess of 300 RPM or from 0 to about 240 circumferential feet per minute. The actual separation of clay from the halite-sylvite is due to the difference in deflection angles of these components. The slightly magnetic clay adheres to the roll surface fractionally longer than the halite-sylvite and describes a slightly lower trajectory. The resultant spread increases during the short free-fall period till gravity predominates following which no further spread occurs. Deflection is also affected by particle mass and the centrifugal force imparted by the rotating roll surface. Thus at a given roll speed the magnetic attraction is overcome by the centrifugal force and deflection is haphazard at best.

Given specific gravities of sylvinite ore components of 1.98 for sylvite, 2.10 to 2.20 for halite; and 2.22 to 2.70 for the water insolubles, a very small deflection angle exists — probably in the order of 2° to 5°. Attempts to measure this were unsuccessful.

Theoretically, feed rate should increase proportionately to roll speed for a given particle bed thickness on the roll surface. Though contact time also decreases, acceptable separation of clay should be possible till centrifugal forces approach or exceed the magnetic attraction.

A dependable study on the effect of roll speed could not be undertaken because particles tended to bounce perceptably as roll speed increased. This introduced an uncontrollable condition which prevented a methodical study. Although a 100 RPM roll speed was finally used, it is thought that speeds of up to 200 RPM could yield adequate results if the splitter head were relocated to exploit the resultant deflection angle to the fullest extent possible.

II FEEDER VIBRATION AMPLITUDE

This is infinitely variable and presents the material to the roll surface. For a given feed gate opening, the feed rate increases with increasing vibration amplitude. The difference between a low and the highest setting results in some 25% increase in feed flow, however, as amplitude increases particles bounce and are thrown further down the roll circumference thus limiting contact time. To offset this effect, the feed chute was modified to feed at approximately the ten o'clock position instead of the original twelve o'clock position. Although it was demonstrated that a curtain riding on the lip of the chute effectively eliminates the bouncing and resultant forward component of the particles, most testing was done at a 70 to 80% setting of vibration amplitude.

III FEED RATE

An adjustable gate controls the feed rate and bed depth presented to the roll surface. The ideal is a mono particle layer on the roll. Thicker bed depths generally dictate reprocessing the materials to ensure adequate clay rejection. This does increase total throughput significantly.

IV SPLITTER BLADE

Two splitter blades are located in the discharge hopper at sufficient distance from each other to separate material into three product streams. The least magnetic material splits off first, followed by material which is more magnetic. Particles with the highest magnetic susceptibility are carried over the furthest. In this case, very minor quantities of clay were sufficiently magnetic to warrant collecting three products and a split was made between "magnetics" and "non magnetics" with the first splitter blade, the second being inactivated. The positioning of the splitter blade is very critical in terms of ensuring good separation of clay. As originally designed, the first splitter blade met the deflected stream at a rather flat angle making differentiation between the magnetic and non magnetic streams haphazard and difficult to reproduce. Consequently, the splitter blade was redesigned to locate parallel to the stream trajectory making selection precise and readily reproducible. Another refinement was a six inch pointer mounted on the adjusting wheel and a fixed position ruler as the scale to facilitate reproducibility of the blade settings.

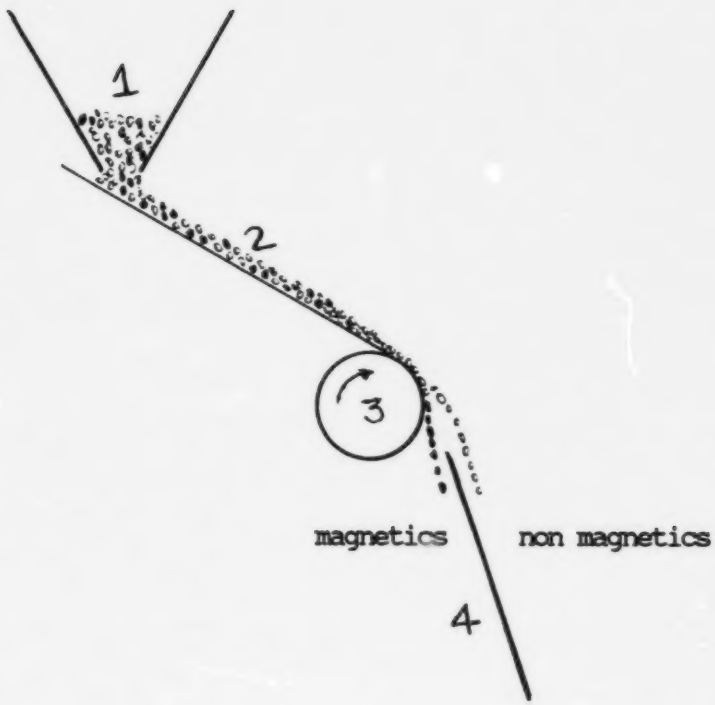
It was found slight setting changes were required to ensure best results whenever feed rates or vibration amplitudes were changed. Major setting corrections were needed to accommodate roll speed changes.

A sketch of the feeding and separating system is appended as Figure 2.

FIGURE 2

BATEMAN PERMROLL

OPERATING FUNCTIONS



Legend:
1. Feed hopper with variable gate
2. Vibrating feeder variable intensity
3. Variable RPM Permroll
4. Splitter blade

TEST PROCEDURE

Ore samples typical of the milling operation were selected as required and sized as test sequences dictated. For the circuit evaluation and salt activation tests, crushing plant discharge was used.

Test lots were 1 kilogram in weight except for salt activation tests which were limited to 500 grams due to equipment constraints.

The clay liberation study involved ore as mined, as well as primary and secondary screen oversizes in the crushing plant. The primary screen oversize is a nominal 2 inch x 3/8 inch material. Secondary screen oversize is a nominal 3 x 6 mesh material.

Gravity separations (heavy liquid) were performed on magnetically processed products to ascertain the effectiveness of the magnetic process. Tests on total materials were completed to establish the degree of clay liberation.